U.S. Department
of Transportation
**Federal Aviation
Administration**

Advisory Circular

Subject: **ALTIMETER ERRORS AT COLD TEMPERATURES** **Date: x/x/xx** **Initiated by:** **AFS-400** **AC No:** **91-XX** **Change:**

1. PURPOSE. This advisory circular (AC) informs about a potentially hazardous situation that occurs at extreme temperatures. At extreme temperatures, your altimeter may give you significantly erroneous readings. The situation is especially dangerous at cold extremes, because you may be much lower than your altimeter indicates. This error might be as much as 1000 feet or more, and if you rely solely on your altimeter reading you might not maintain an altitude necessary to clear obstructions.

2. FOCUS. This AC is directed to pilots, air traffic controllers and flight operations personnel.

3. RELATED READING MATERIAL. This AC establishes Federal Aviation Administration (FAA) policy on altimeter error under extreme temperature conditions.

4. DISCUSSION.

a. As a pilot, what should you do to respond to this hazard?

(1) You are responsible for adjusting for the error in altimeter readings. When you are under Air Traffic Control (ATC) and have been issued an altitude, do not assume that the altitude has been adjusted for cold weather-induced altimeter errors. If you have any doubt about the altitude, you can request a higher altitude.

(2) Make sure your altimeter is accurate. When your aircraft is on the ground, your altimeter should not be in error by more than 75 feet compared to actual airport elevation. If it is, you must have your altimeter serviced and approved by certified maintenance personnel.

(3) When you plan your flight, take into account any temperature extremes you anticipate. You should be especially alert when temperatures reach 10° C or more below standard. Calculate the approximate error and plan to adjust your altitude accordingly. We provide information on how to make these calculations in Appendices 1 and 2.

(4) During flight, assume that your altimeter is always in error. Make sure you set your altimeter correctly. Stay aware of in-flight conditions, especially outside air temperature. Be alert to inversions or other conditions which might unexpectedly affect outside air temperature. When surface temperatures are unusually cold, it is particularly important to make altitude adjustments on initial, intermediate and final approach segments in any obstacle-rich environment. You can use the formula in Appendix 1 or the table in Appendix 2 to make the adjustments.

(5) Do not make adjustments for cold temperature to altimeter settings issued by ATC, Air Terminal Information Service (ATIS) or Automated Weather Observation System (AWOS), nor to radar altitudes assigned by a US Air Traffic Facility or international ATS facility that already considers cold temperature effects.

b. What should air traffic control do to respond to this hazard?

(1) You are responsible for cold temperature adjustment when the pilot is under your control and you have assigned him to an altitude. You can use the information in Appendices 1 and 2 to determine needed adjustments.

(2) Make sure your pilots are aware of this hazard, especially during cold temperature extremes. Remind your pilots to correct their altimeter settings during flight, especially when they plan to fly to an airport at a higher elevation or over mountains or other obstructions.

(3) If a pilot requests a higher altitude than you've assigned, because he has concerns about temperature influences, then assign a higher altitude.

c. Supplemental Information.

(1) How Altimeters Work. Most aircraft depend on pressure altimeters for their altitude readings. These instruments do not read altitude directly, as do radar altimeters. Rather, they read air pressure, and translate that into an estimate of altitude. The pressure altimeter used in aircraft is a relatively accurate instrument for measuring air pressure at your flight level. However, the altitude information indicated by an altimeter, although technically "correct" as a measure of pressure, may differ greatly from the actual height of the aircraft above mean sea level or above ground.

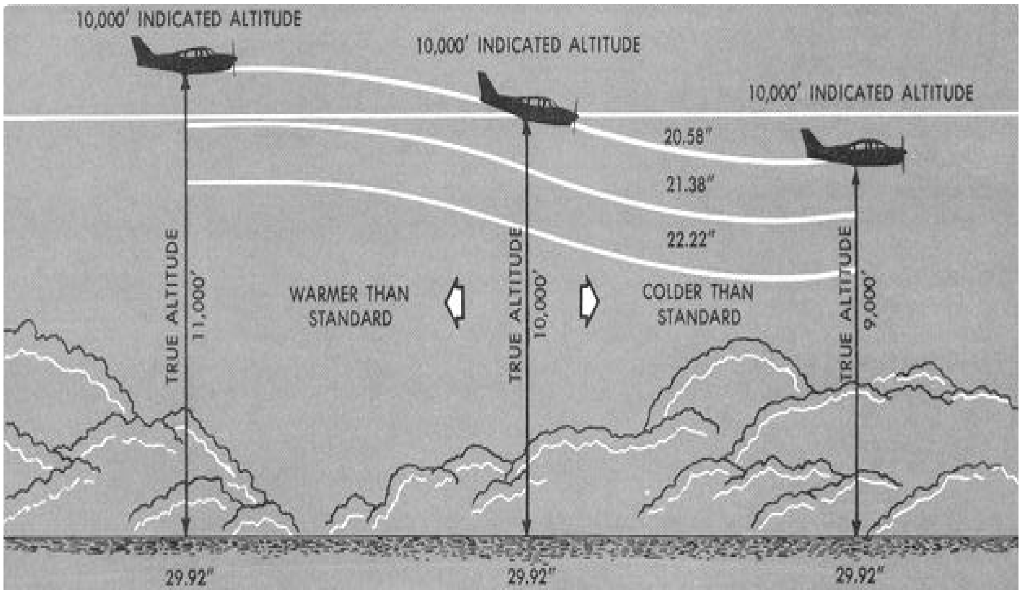
(a) Pressure altimeters are calibrated to indicate true altitude under International Standard Atmosphere (ISA) conditions. The ISA assumes that the atmosphere is a perfectly dry gas with the following conditions:

1. mean sea level pressure of 29.92 inches of mercury,

2. mean sea level temperature is 15°C, and

3. rate of decrease of temperature with height is 1.98°C per 1,000 feet to the height at which the temperature becomes –56.5°C, after which the temperature remains constant.

Figure 1. Altimeter Reading Deviation Due to Temperature



(b) Clearly, these "standard" conditions rarely exist. Any deviation from this standard may result in an incorrect reading on the altimeter. When the temperature is higher than standard, your altitude will probably be higher than the altimeter indicates. When the temperature is lower than standard, your altitude will probably be lower than the altimeter indicates. Extremely cold temperatures may result in altimeter errors greater than 10% of the indicated reading.

(2) The Altimeter Subscale. Air pressure varies with time and place, depending on weather conditions. Altimeters include a subscale that you set to correct for these variations in air pressure. By setting this subscale correctly, you tell the altimeter what to use for "zero" on its scale. You should set the subscale initially based on the reading provided by your airport of origin. You should reset this subscale periodically during flight to correct for changes in air pressure. Make sure you set the subscale accurately. If you erroneously set it too high, the altimeter reading probably will be too high and your aircraft will be at a lower level than the altimeter indicates. If you erroneously set the subscale too low, the altimeter reading probably will be too low and your aircraft will be at a higher level than the altimeter indicates.

(3) Problems on Approaches. It's particularly important to make altitude adjustments on initial, intermediate and final approach segments in mountainous areas or any obstacle-rich environment because unusually cold surface temperatures can cause significant differences between true and indicated altitudes. Adjustments may also be appropriate for minimum en route altitudes, minimum vectoring altitudes, "drift down" flight paths in obstacle-rich environments, or takeoff flight paths, when extreme cold temperature effects are not otherwise considered. The magnitude of temperature-induced altimeter errors decrease as the height above and distance from the airport surface decreases.

(a) Mountains can be a source of altimeter errors. Winds can be deflected around large single peaks or ranges. Valleys of mountain ranges can cause winds to increase in speed (Venturi effect) which results in local decrease in pressure (Bernoulli's Principle). A pressure altimeter within such an airflow would be subject to additional errors in altitude indication.

(b) Winds blowing over a mountain range at speeds in excess of about 50 KT and in a direction perpendicular (within 30°) to the main axis of the mountain range often create phenomena known as "Mountain" or "Standing Waves". The effect of a mountain wave often extends as far as 100 NM downwind of the mountains and to altitudes many times higher than the mountain elevation. Although most likely to occur in the vicinity of high mountain ranges such as the Rockies, mountain waves do occur in the Appalachians as well.

(4) Research on the Impact of Extreme Temperatures on Altimeters. Considerable research has been done both in the United States and in other countries to determine the extent of altimeter error in areas of extreme cold temperatures. The results of this research are captured in the formula in Appendix 1 and tables in Appendix 2.

(5) Using Other Cold Temperature Correction Tables. If you get a different cold temperature altitude correction table(s) or methods from a "State of the aerodrome", an aircraft manufacturer, International Civil Aviation Organization (ICAO), another authority for that State, or operator (e.g., simplified tables or methods), you may use those alternate tables or methods in lieu of the formula in Appendix 1 or tables in Appendix 2. However, make sure the alternate tables or methods ensure suitable terrain and obstacle clearance. Their use should be compatible with ATS procedures or clearances.

(6) US Pilots Operating Outside the United States. While procedure and airspace planners often consider extreme temperature conditions, there may be procedures in some locations, in the United States and in other countries, where extreme temperatures were not considered. If you have any doubts or questions about safe obstacle clearance, make sure you allow for possible errors when planning your flight. Be aware of any temperature correction tables provided by different countries or aircraft manufacturers.

(7) International Operators Flying to the US. International operators flying in the US may use methods acceptable to the authority of the State of the operator or they may use the FAA approved formula in Appendix 1 or tables in Appendix 2.

(8) Extreme Conditions Other than Cold Temperatures. Although extreme cold causes the most dangerous errors in altimeter readings, you should also be aware of extreme heat and unusually low surface pressures.

/s/
L. Nicholas Lacey
Director, Flight Standards Service

APPENDIX 1. Below Standard Temperature Altitude Adjustment Formula

Cold Weather Correction Formula:

$$C = \frac{h(15 - t_0)}{273 + t_0 - .5k(e + h)},$$

where

h is the height above the facility
k is the standard temperature lapse rate (**.00198° C/ft** or .**0065° C/m**)
e is the facility elevation
t is the facility temperature
t_0 is the facility temperature adjusted to mean sea level, $t_0 = t + ke$
and ***C*** is the altitude correction value.

For example: given ***h* = 3000'**, ***k* =.00198**, ***e* =1500'**, ***t* = -40° C**, then

$$\begin{aligned} C &= \frac{h(15 - t_0)}{273 + t_0 - .5k(e + h)} \\ &= \frac{3000(15 - (-40 + .00198 \times 1500))}{273 + (-40 + .00198 \times 1500) - .5 \times .00198(1500 + 3000)} \\ &= \frac{3000(15 + 37.03)}{273 - 37.03 - 4.455} \\ &= 674.2' \end{aligned}$$

This value should be rounded up to the nearest **10'**, i. e., ***C* = 680'**.

Note: The table value gives a more conservative correction of **720'**.

APPENDIX 2. Below Standard Temperature Altitude Adjustment Tables

Facility Elevation Equal to or Greater than 8000 ft MSL

Height above Facility in Feet

Facility Temp °C	200	300	400	500	600	700	800	900	1000	1500	2000	3000	4000	5000	Temp C° from ISA
-6	10	10	10	10	20	20	20	20	20	30	50	70	90	110	-5
-16	20	20	30	40	40	50	50	60	70	100	130	190	250	320	-15
-26	30	40	50	60	70	80	90	100	110	160	220	320	430	540	-25
-36	40	50	70	80	100	110	130	140	160	240	310	470	630	790	-35
-46	50	70	90	110	130	150	170	190	210	320	420	630	840	1060	-45
-56	60	80	110	140	160	190	220	240	270	400	540	810	1080	1360	-55
-66	70	100	140	170	200	230	270	300	330	500	670	1000	1340	1680	-65

Facility Elevation Equal to or Greater than 6000 ft but less than 8000 ft MSL

Height above Facility in Feet

Facility Temp °C	200	300	400	500	600	700	800	900	1000	1500	2000	3000	4000	5000	Temp C° from ISA
-2	10	10	10	10	20	20	20	20	20	30	40	60	80	100	-5
-12	20	20	30	30	40	50	50	60	60	90	120	180	250	310	-15
-22	30	40	50	60	70	80	90	100	110	160	210	320	420	530	-25
-32	30	50	60	80	90	110	120	140	150	230	310	460	610	770	-35
-42	50	70	90	110	130	150	170	190	210	310	410	610	820	1030	-45
-52	60	80	110	130	160	180	210	240	260	390	520	780	1050	1320	-55
-62	70	100	130	160	200	230	260	290	320	480	650	970	1300	1630	-65

Facility Elevation Equal to or Greater than 4000 ft but less than 6000 ft MSL

Height above Facility in Feet

Facility Temp °C	200	300	400	500	600	700	800	900	1000	1500	2000	3000	4000	5000	Temp C° from ISA
2	10	10	10	10	20	20	20	20	20	30	40	60	80	100	-5
-8	20	20	30	30	40	50	50	60	60	90	120	180	240	300	-15
-18	20	30	40	50	60	80	90	100	110	160	210	310	410	510	-25
-28	30	50	60	80	90	110	120	140	150	220	300	450	600	750	-35
-38	40	60	80	100	120	140	160	180	200	300	400	600	800	1000	-45
-48	50	80	100	130	150	180	200	230	260	380	510	760	1020	1280	-55
-58	70	100	130	160	190	220	250	280	310	470	630	940	1260	1580	-65

Facility Elevation Equal to or Greater than 2000 ft but less than 4000 ft MSL

Height above Facility in Feet

Facility Temp °C	200	300	400	500	600	700	800	900	1000	1500	2000	3000	4000	5000	Temp C° from ISA
6	10	10	10	10	20	20	20	20	20	30	40	60	80	100	-5
-4	20	20	30	30	40	40	50	60	60	90	120	180	230	290	-15
-14	20	30	40	50	60	70	80	90	100	150	200	300	400	500	-25
-24	30	50	60	80	90	100	120	130	150	220	290	440	580	730	-35
-34	40	60	80	100	120	140	160	180	200	290	390	580	780	980	-45
-44	50	80	100	130	150	180	200	220	250	370	490	740	990	1240	-55
-54	60	90	120	160	190	220	250	280	310	460	610	920	1230	1540	-65

Facility Elevation less than 2000 ft MSL

Height above Facility in Feet

Facility Temp °C	200	300	400	500	600	700	800	900	1000	1500	2000	3000	4000	5000	Temp C° from ISA
10	10	10	10	10	20	20	20	20	20	30	40	60	80	90	-5
0	20	20	30	30	40	40	50	50	60	90	120	170	230	280	-15
-10	20	30	40	50	60	70	80	90	100	150	200	290	390	490	-25
-20	30	50	60	70	90	100	120	130	140	210	280	420	570	710	-35
-30	40	60	80	100	120	130	150	170	190	280	380	570	760	950	-45
-40	50	80	100	120	150	170	190	220	240	360	480	720	970	1210	-55
-50	60	90	120	150	180	210	240	270	300	450	590	890	1190	1500	-65

Enter tables at facility elevation, next colder temperature, and next higher height above facility.

e.g., if the facility elevation is 2200 ft MSL with a facility temperature of -17° C, with a charted MDA of 2950 ft, then enter the 2000' to 4000' table at -24° C and 800 ft for an adjustment of 120 ft.